CONFORMAL COATINGS FOR PRINTED CIRCUIT ASSEMBLIES

REPORT NO. 3

DA-36-039-sc-89136

THIRD QUARTERLY REPORT

RUARY 1, 1962 TO APRIL 15, 1962

U. S. ARMY SIGNAL SUPPLY AGENCY
STANDARDIZATION ENGINEERING DIVISION
FT. MONMOUTH, NEW JERSEY

MOTOROLA INC.
Military Electronics Division · Chicago Center
1450 NORTH CICERO AVENUE, CHICAGO 51, ILLINOIS

CONFORMAL COATINGS

FOR

PRINTED CIRCUIT ASSEMBLIES

Third Quarterly Report for the period of Feb. 1, 1962 to April 15, 1962.

Signal Corps Contract Number DA-36-039 SC89136

Department of the Army Project Number: 5999-004

Placed by: United States Army Signal Supply Agency
Standardization Engineering Division
Fort Monmouth, New Jersey

Contractor: Motorola, Inc.
Chicago Center
1450 N. Cicero Ave.
Chicago 51, Illinois

Signal Corps Contract Number DA-36-039 SC-89136

Technical Requirements for PR & C Number 61-SIMSA-482
dated 22 March 1961.

Dept. of the Army Project Number: 5999-004

Report Submitted by: Anthony J. Beccasio
Anthony J. Beccasio
Project Engineer

Approved by: Robert D Andreasen
Robert Andreason
Manager, Engineering Services

CONFORMAL COATINGS FOR

PRINTED CIRCUIT ASSEMBLIES

Third Quarterly Report for the period of Feb. 1, 1962 to April 15, 1962.

Objective:

Phase A: Evaluate commercially available conformal coating materials used as protective coatings on printed circuit boards in order to obtain data for the preparation of a three services coordinated military specification which will provide sufficient physical, mechanical and electrical properties to assure satisfactory performance of printed circuit assemblies over long storage periods and under high humidity conditions.

Phase B: Investigate a method of removing the coating from the board to permit replacement of parts when necessary without impairing the functional operations of the unit.

Phase C: Evaluate, for possible ungrading purposes, allowable minimum spacings between conductors on uncoated and coated boards as described in paragraphs 5.1.5 of MIL-STD-275A.

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APPENDIX

PURPOSE

PHASE A The purpose of this project is to evaluate commercially available conformal coating materials used as protective coatings on printed circuit boards in order to obtain data for the preparation of a three services coordinated military specification which will provide sufficient physical, mechanical, and electrical properties to assure satisfactory performance of printed circuit assemblies over long storage periods and under high humidity conditions.

In this report, the Stages are defined as follows:-

Stage A

Investigation of epoxy resin conformal coatings on XXXP, glass-epoxy and paper-epoxy copper clad laminate series specified in MIL-P-13949B and PR & C 61-SIMSA-482.

Task 1 Two-part epoxy resin coating systems

Part 1 Characteristics of epoxy resin coatings studied.
Part 2 Curing Schedule.

Task 2 Test Panels used.

Task 3 Precoating Preparation of Surface

Part 1 Cleaning.
Part 2 Soldering.

Task 4 Method of Coating Application

Task 5 Physical and Electrical Properties of Epoxy Resin Coating Systems.

Part 1 Appearance and Adhesion.

Part 2 Thickness measurements.

Part 3 Dielectric Constant and Dissipation Factor of disc specimens.

Part 4 Dissipation Factor and Q-Factor of coated test panels.

Part 5 Dielectric Withstanding Voltage (initial).

Part 6 Thermal cycling.

Part 7 Dielectric Withstanding Voltage (after thermal cycling).

PURPOSE
(Continued)

Part 8 Insulation resistance and appearance under moisture conditions.

Part 9 Dielectric Withstanding Voltage (after moisture test).

Part 10 Abrasion Resistance.

Part 11 Ruggedization.

Part 12 Flexibility.

Stage B.

Investigation of polyurethane resin conformal coatings on XXXP and glass-epoxy, copper-clad laminate series specified in MIL-P-13949B and PR & C 61-SIMSA-482.

Tasks 1 - 5 The same as Stage A where application is feasible.

Stage C.

Investigation of Silicone-based polymer coatings on glass-epoxy and silicone-glass copper-clad laminate series specified in MIL-P-13949B.

Tasks 1 - 5 The same as Stage A where application is feasible.

Stage D.

Investigation of MIL-V-173 varnishes on glass-epoxy, XXXP and paper-epoxy laminates per MIL-P-13949B.

Tasks 1 - 5 The same as Stage A where application is feasible.

PHASE B Investigate a method of removing the coating from the board to permit replacement of parts when necessary, without impairing the functional operations of the unit.

Stage A. Investigation of chemical stripping of conformal coating as a method of repairing printed wiring assembly.

Stage B. Investigation of mechanical stripping of conformal coating as a method of repairing printed wiring assembly.

Stage C. Investigation of chemical-mechanical stripping of conformal coating as a method of repairing printed wiring assembly.

PHASE C Evaluate, for possible upgrading purposes, allowable minimum spacings between conductors on coated and uncoated boards as described in Paragraph 5.1.5 of MIL-STD-275A.

ABSTRACT
PHASE A

Stage A

Investigation of epoxy resin conformal coatings on XXXP, glass-epoxy, and paper-epoxy copper-clad laminate series specified in MIL-P-13949B and PR & C 61-SIMSA-482.

Task 5 Physical and Electrical Properties of Epoxy Resin Coated Systems.

Part 10 Abrasion Resistance

Epoxies C, F and I were coated on 4"x 4" steel plates and subjected to 200 cycles of abrasion on a Tabor Abrasor Machine as specified in Method 6192 of FED-STD-141. Analysis of the results showed that the wear index was higher in a solvent-based systems than in 100% solids systems.

Part 11 Ruggedization

Epoxies C, F and I were coated on printed circuit assemblies having a sampling of the most common types of components found on printed circuit assemblies. It was found that, when the coated assemblies were subjected to a high frequency vibration specified in Method 204A of MIL-STD-202B, there was no evidence of cracking or crazing of the coatirg was noted

Part 12 Flexibility

Epoxies C, F and I were coated to a thickness of 0.012± 0.007 inches on 0.010 inches thick tin foil. The coating was allowed to cure according to the manufacturer's instructions. When the flexibility test was performed according to Method 6221 of FED-STD-141, it was found that none of the epoxy coatings showed evidence of cracking or crazing.

Stage B

Investigation of polyurethane resin conformal coatings on XXXP, glass-epoxy and paper-epoxy, copper clad laminate series specified in MIL-P-13949B and PR & C 61-SIMSA-482.

Task 5 Physical and Electrical Properties of Polyurethane Resin Coating Systems.

Part 10 Abrasion Resistance

Polyurethanes AA,BB,CC and HH were coated on 4 x 4 inch steel plates and subjected to 200 cycles of abrasion on a Tabor Abrading Machine specified in Method 6192 of FED-STD-141. Analysis of the results revealed that the wear index did not differ much between polyurethane samples, but had lower wear indices than the epoxy coatings.

Part 11 Ruggedization

When the polyurethane coatings were subjected to the same test described in Part 11, Phase 5 of Task A, there was no evidence of cracking or crazing of the coating.

Part 12 Flexibility

When polyurethanes coatings AA,BB,CC and HH were tested according to method 6221 of FED-STD-141, it was found that all the coatings passed except polyurethane HH which cracked when flexed.

Stage C

Investigation of silicone - based polymer coatings on glass-epoxy copper clad laminate series specified in MIL-P-13949B.

Task I Silicone - based polymer coatings

Part 1 - Characteristics of silicone - based polymer coating systems.

Two silicone - based polymer coatings that were suggested for use on printed circuit assemblies were investigated. These two coatings met the requirements of para. 2b of PR & C 61-SIMSA-482. One coating was a one component type and the other a two component type. Both coatings were solvent-based systems.

Part 2 Curing Schedule

Both coatings were cured at room temperature for 24 hours.

Task 2 Test Panels Used

Test panels used were fabricated from two parallel line pattern (Specimen X) described in Fig. 1, Note 7 of MIL-P-55110, or GE, GB and GF laminates and is shown in the Appendix p. iv.

Task 3 Precoating Preparation of Surface

Part 1 Cleaning

To eliminate all corrosion effects other than from testing of the coating itself, a stepwise cleaning technique for the copper surface of the specimen panels was devised.

Task 4 Method of Coating Application

All specimens were brush coated.

Task 5 Physical and Electrical Properties of Silicone Resin Coating Systems

Part 1 Appearance and Adhesion

A visual check of the coated test panels revealed no evidence of blistering, wrinkling, cracking and peeling of the coating nor corrosion of printed conductors. All coatings exhibited good adhesion to specimen test panels.

Part 2 Thickness measurements

All specimen test panels were coated to a thickness of 0.004 ± 0.002 inches.

Part 4 Dissipation Factor and Q-Factor of Coated Test Panels

The dissipation factor and Q-value of the coating was determined, using Specimen X, at 1,50 and 100 mc. by calculating the relative differences in Q of the coated and uncoated test patterns. It was found that the Q-value and dissipation factor difference between the coated and uncoated patterns did not change much as the frequency increased.

Stage D

Investigation of MIL-V-173 varnishes for use as conformal coatings on glass-epoxy XXXP and paper-epoxy laminates per MIL-P-13949B.

Task 1 MIL-V-173 Varnishes

Part 1 Characteristics of MIL-V-173 Varnishes

Two MIL-V-173 varnishes, commonly used at Motorola, were chosen for use as conformal coatings. These two coatings met the requirements of para. 2b of FR & C 61-SIMSA-482. Both coatings were of the one component type and are listed in QPL-173.

Part 2 Curing Schedule

Both coatings were cured for 5 hours at room temperature.

Task 2 Test Panels Used

The test panels used wer fabricated, from two parallel line pattern described in Fig. 1, note 7 of MIL-P-55110, on type PP,PE,GE,GB and GF laminates.

Task 3 Precoating Preparation of Surface

Part 1 Cleaning

The same cleaning method stated in Task C, phase 3, part 1 was used.

Task 4 Method of Coating Application

All specimens were brush coated.

Task 5 Physical and Electrical Properties of MFP Varnish Coatings Systems.

Part 1 Appearance and Adhesion

A visual check of the coatings revealed both of the coatings wrinkled when cured. However, both coatings exhibited good adhesion to specimen test panels. When MFP varnishes are coated to thickness above 0.002 inches, wrinkling occurs because of the coating drying initially on the surface.

Part 2 Thickness Measurements

All specimen test panels were coated to a thickness of 0.004 ± 0.002 inches.

Part 4 Dissipation Factor and Q-Factor of Coated Test Panels

The dissipation factor and Q-value of the coating was determined, using specimen X,at 1,50 and 100 mc. It was found that the Q-value decreased with increasing frequency. Q-values of the coatings were higher on the glass-epoxy than the paper base laminate indicating good dielectric properties of MFP coatings.

PHASE B

Stage A

Investigation of Chemical stripping of conformal coatings to facilitate Repair of printed wiring assembly.

Twenty eight solvents that were recommended for stripping of epoxies and polyurethanes, were evaluated as to corrosivity of copper and stripping effect on epoxies and polyurethane coatings. It was found that twelve of the solvents softened and/or lifted the polyurethane and epoxy coating without corroding the copper conductors.

Stage B

Investigation on Mechanical Stripping of Conformance Coating to facilitate repair of printed wire assembly.

Hot and "Cool" soldering iron techniques were evaluated. It was found that a hot iron whose tip is a 600°F, chars and redeposits the material on the circuitry. However, when a "cooler" iron, whose tip temperature is between 350 to 400°F, is used the resin softens which then can be scraped off easily.

Stage C

Investigation on Chemical-Mechanical Stripping of Conformal Coating to Facilitate repair of printed wiring assembly.

A technique, which includes techniques evaluated in Stages A and B, was developed and given a pilot run through our production facility. It was found that an assembly can be repaired with the minimum of time and with less damage to the printed wiring assembly using this technique.

PHASE C

Evaluate, for possible upgrading purposes, allowable minimum spacings between conductors on coated and uncoated boards as described in para. 5.1.5 of MIL-STD-275A.

130 test patterns, shown in the Appendix, p. v, were fabricated and coated with the epoxy and polyurethane coatings. A circuit capable of handling 50 watts was designed for each spacing and is shown in the Appendix p. vi. Spacings will be tested at various voltage ratings, as specified in para. 5.1.5 of MIL-STD-275A, vs. altitude to determine if power requirements can be upgraded.

PUBLICATIONS, LECTURES, REPORTS AND CONFERENCES

On March 24, 1962, the writer visited the Dow Corning Corporation to obtain information on silicone coatings and their effect on printed wiring boards.

FACTUAL DATA

PHASE A

Stages A & B

Investigation of epoxy and polyurethane conformal coatings on paper-base and glass-epoxy copper-clad laminate series specified in MIL-P-13949B.

Task 5 Physical and Electrical Properties of Epoxy and polyurethane Conformal Coatings.

Part 10 Abrasion Resistance (Wear Index)

Epoxy and polyurethane coatings were brush coated on 4 inch x 4 inch steel plates to a thickness of 0.012 ± 0.007 inches. The coated panels were initially cured according to the manufacturer's information and then allowed to cure for seven days prior to performing the abrasion tests. For each epoxy coating, three coated plates were tested and their results averaged. The wear index of the coating was determined as follows:-

The coated steel plates were weighed initially to the nearest 0.1 milligram and the weights recorded. They were then placed on the turntable of the Tabor Abraser Machine and subjected to 200 cycles of abrasion using CS-10 Calibrase wheels with 1000 gram load applied to the wheels. After the test, the coated plates were re-weighed to the nearest 0.1 milligram and the weights recorded. The wear Index was calculated as follows:-

$$\text{Wear Index (WI)} = \frac{(A-B)\,1000}{C}$$

A = weight of test specimen before abrasion

B = weight of test specimen after abrasion

C = number of cycles of abrasion recorded.
This data is presented in the Appendix, page vii

Part 11 Ruggedization

The epoxy and polyurethane coatings were coated over some printed circuit assemblies containing "dummy" components. The heaviest component mounted on these boards weighed 31 grams. Coating thickness varied from 0.003 inches for epoxy F to 0.015 inches for Epoxy C. Two coated assemblies were run for each coating. Three uncoated assemblies were tested with the coated assemblies. The assemblies were subjected to a vibration test specified in Method 201A of MIL-STD-202B and then reexamined for evidence of cracking or crazing of coating.

Part 12 Flexibility

The epoxy and polyurethane coatings were brush coated onto 0.010 inch thick tin foil to a thickness of 0.012 ± 0.007 inches. The coatings were cured according to the manufacturers specifications. The specimens were allowed to cure at room temperature conditions prior to testing. The flexing test was performed using the following technique:-

> The test panel was placed coated side upper-most on a 1/8 inch diameter stainless steel rod at a point equally distant from the top and bottom edges of the panel. The coated panel was bent double in about 1 second. The coating was examined at the bend for evidence of cracking or crazing.

Stage C

Investigation of silicone-based polymer coatings on glass-epoxy and silicone-glass copper clad laminate series specified in MIL-P-13949B.

Task 1 Silicone-based polymer coatings.

Part 1 Characteristics of silicone-base polymer coatings.

The silicone coatings were reevaluated because the two silicone coatings discussed in Quarterly Report No. 2 did not meet the specified tests. One silicone coating wrinkled when cured and the other showed evidence of copper corrosion when exposed to humidity conditions. The two coatings that will be described in this report were solvent-based coatings. Of the two silicone coating desc ibed, one is a two component system and the other a one component type.

Part 2 Curing Schedule

The two coating systems were cured at room temperature for 24 hours.

Task 2 Test Panels used

The test panels used were the two parallel-lines-pattern (Specimen X) fabricated in accordance with Figure 1, Note 7 of MIL-P-55110. A diagram of these test patterns appears in the Appendix, Table III at the end of this report.

The test panels were prepared on the following copper-clad laminates, 0.062 inches thick, copper-one side with one and two ounces:

Type GE - Epoxy resin - glass fabric base.

Type GB - Epoxy resin - glass fabric base, general purpose, temperature resistant.

Type GF - Epoxy resin - glass fabric, flame retardant.

For each silicone coating, three coated test panels and 1 uncoated test panel, for use as a control, of each of the above mentioned laminates was used.

Task 3 Precoating Preparation of Surface

Parts 1 and 2 Cleaning and Soldering

Same procedure as described in Phase 3 of Task C.

Task 4 Method of coating application

All test specimens were brush coated.

Task 5 Physical and Electrical Properties of MIL-V-173 varnishes

Part 1 Adhesion and appearance

After the specimen panels were coated and cured, they were visually examined for blistering, wrinkling, cracking and peeling of the coating and corrosion of the conductors.

Part 2 Thickness Measurements

Procedure described in Part 2, phase 5 of Task C was followed.

Part 4 Q-Factor and Dissipation Factor of the Coated Test Panels

Procedure described in Part 4, phase 5 of Task C was followed.

PHASE B

Stage A

Investigation of chemical stripping of conformal coating as a method of repairing printed wiring assembly.

Twenty eight solvents and compounds that were recommended for use as strippers of epoxy and polyurethane coatings were evaluated as to the following parameters:-

(1) Corrosion effect on copper.

(2) Effectiveness as a stripper of epoxy and polyurethane coatings.

The procedure for determining these parameters is as follows:-

(1) Corrosion effect on copper.

1 x 3 inch strips of Type PP, PE, GE, GF and GB copper-clad laminates were dipped into the twenty eight solvents. Prior to dipping into the solvents, the copper surface was

(1) Resonate Q-Meter (1) without specimen and note Q_2 (Voltmeter reading) and C_2 readings.

(2) Place test specimen in Q-meter Circuit and resonate circuit again and note Q_1 and C_1 readings.

(3) Calculate Q_x of coating as follows:-

$$Q_x = \frac{Q_1 Q_2 (C_2 - C_1)}{(Q_2 - Q_1) C_1}$$

From this the dissipation factor is:-

$$DF = \frac{1}{Q_x}$$

This data is presented in the Appendix, page ix.

Stage D

Investigation of MIL-V-173 varnishes for use as conformal coatings on paper-base and glass-epoxy laminates specified in MIL-P-13949B.

Task 1 MIL-V-173 varnishes.

Part 1 Characteristics of MIL-V-173 varnishes

These varnishes are of the moisture-and-fungus-resistant type, consisting of a para-phenyl phenol-formaldehyde resin in combination on the tung oil and suitable solvents. They are made fungistatic by the addition of 7% salicylanilide. The two varnishes evaluated are on QPL-173 and are commonly used at Motorola.

Part 2 Curing Schedule

The varnishes were cured at room temperature for 5 hours.

Task 2 Test Panels Used

Test panels used are the same as described in Task 2 of Stage C, except that the paper-base laminates are included in the evaluation.

Task 3 Precoating Preparation of Surface

Parts 1 and 2 Cleaning and Soldering

Same procedure as described in Phase 3 of Task C.

Task 4 Method of coating application

All test specimens were brush coated.

Task 5 Physical and Electrical Properties of MIL-V-173 varnishes

Part 1 Adhesion and appearance

After the specimen panels were coated and cured, they were visually examined for blistering, wrinkling, cracking and peeling of the coating and corrosion of the conductors.

Part 2 Thickness Measurements

Procedure described in Part 2, phase 5 of Task C was followed.

Part 4 Q-Factor and Dissipation Factor of the Coated Test Panels

Procedure described in Part 4, phase 5 of Task C was followed.

PHASE B

Stage A

Investigation of chemical stripping of conformal coating as a method of repairing printed wiring assembly.

Twenty eight solvents and compounds that were recommended for use as strippers of epoxy and polyurethane coatings were evaluated as to the following parameters:-

(1) Corrosion effect on copper.

(2) Effectiveness as a stripper of epoxy and polyurethane coatings.

The procedure for determining these parameters is as follows:-

(1) Corrosion effect on copper.

1 x 3 inch strips of Type PP, PE, G.. GF and GB copper-clad laminates were dipped into the twenty eight solvents. Prior to dipping into the solvents, the copper surface was

scrubbed with pumice to remove oxides and residues. The copper clad laminated were dipped for 15 minutes after which they were allowed to dry overnight. The laminates were then examined under the microscope for attack of copper as well as attack on the laminate.

(2) Effectiveness of stripping of epoxy and polyurethane coatings. A few drops of the strippers were placed on coated epoxy and polyurethane specimens. After 15 and 30 minutes the coating was examined for attack.

The data for this investigation appears on the Appendix, p. x.

Stage B

Investigation of mechanical stripping of conformal coating as a method of repairing printed wiring assembly.

The only technique investigated is the use of a 60-watt soldering iron in removing the coating. The tip temperature was controlled by varying the line voltage. This technique utilizes burning or softening the coating with a hot soldering iron and then removing the coating with a suitable scraping tool.

Stage C

Investigation of chemical-mechanical stripping of conformal coating as a method of repairing printed wiring assembly.

This technique involves the use of a chemical stripper as well as hot solder iron to effect removal of the conformal coating. This technique was evaluated in production where 75 boards that were coated had to have several resistors changed,

PHASE C

Evaluate, for possible upgrading purposes, allowable minimum spacings between conductors on coated and uncoated boards as described in paragraphs 5.15 of MIL-STD-275A.

A test pattern was devised for this test that duplicates the spacings described in Tables I through IV of MIL-STD-275A. A sketch of this test panel appears in the Appendix, page v.

A test circuit was developed and is shown in the Appendix, page vi. The coated and uncoated panels would be placed in an altitude chamber and the voltages described in Tables I through IV of MIL-STD-275A will be applied to each spacing. Coated specimens will be evaluated at 50,000 feet whereas uncoated specimens will be evaluated at 10,000 feet. After the power is applied to the circuit, the resistance across the spacings will be measured to determine when breakdown occurs.

CONCLUSION

PHASE A

Stages A & B

Investigation of epoxy resin and polyurethane conformal coatings on XXXP, glass-epoxy and paper-epoxy copper-clad laminate series specified in MIL-P-13949B.

Task 5 Physical and Electrical Properties of Epoxy Resin and Polyurethane Coating Systems.

Part 10 Abrasion Resistance

Analysis of the wear index results for epoxy coatings reveals that there is a marked difference in the data. This difference is attributed to the percentage solids of the coating system. When the solids content is low, then the wear index is high. This is due to the possibility of solvent being trapped in the cured coating. This is demonstrated in the following cases:

Epoxy C	100% solids	wear Index = 0.043
Epoxy F	20% solids	wear Index = 0.130
Epoxy I	60% solids	wear Index = 0.070

The polyurethanes, on the other hand, exhibited a higher degree of abrasion resistance then t epoxies. This is evidenced from the results. Polyurethane GG exhibited a higher wear index than polyurethanes AA and BB. However, no conclusion can be drawn whether this is caused by solvent entrappment or not.

Part 11 Ruggedization

When the assemblies coated with epoxy and polyurethanes coatings were subjected to high and low frequency vibration, there was no evidence of cracking or crazing of the coating. One interesting fact can be concluded from this test, that is the

thickness of the coating does not enhance better ruggedization properties of the assemblies. This fact is only true if good assembly techniques are followed, that i. making sure that the bodies of components are touching the surface of the board wherever possible.

Part 12 Flexibility

When the flexibility test was performed, it was found that all specimens, epoxy and polyurethane, passed except polyurethane HH which cracked severely when fluxed. Again, in this test, thickness of the coating did not enhance better flexibility.

Stages C and D

Investigation of silicone - based polymers and MFP varnishes for use as conformal coatings on the paper base and glass-epoxy laminate series specified in MIL-P-13949B and PR & C 61-SIMSA-482.

Task 1 Silicone and MFP coating systems

Part 1 Characteristics of silicones and MFP varnish coating systems.

All the silicone and MFP varnish coating systems studied met the following characteristics:

(a) Suitability for dip, spray or brush coat application.

(b) Transparency when fully cured.

(c) Cured at room temperature.

(d) Coating formulation fungus inert.

The MFP varnishes studied were all one component systems whereas the silicones were one and two component systems.

Part 2 Curing Schedule

All MFP varnish coatings were cured at room temperature for 5 hours.

All silicone coatings were cured at room temperature for 24 hours.

Task 4 Method of Coating Application

All coatings were brush coated on specimen test panels.

Task 5 Physical and Electrical Properties of MFP and Silicone coating systems.

Part 1 Appearance and Adhesion of coatings

The test panels coated with the silicone coatings exhibited no blistering, wrinkling, cracking, or peeling of the coating and no corrosion of printed conductors. These coatings also exhibited good adhesion to test panels. However, the MFP coated panels showed a wrinkled condition after curing.

Part 2 Thickness measurements

All specimen test panels were coated to a thickness of 0.004 ± 0.002 inches.

Part 4 Q-Factor and Dissipation Factor of the Coated Boards.

Analysis of the results showed that the highest Q-values were obtained with the glass-epoxy laminates as compared to the paper-base materials. Due to the thinness of the coatings, the Q-values did not exhibit a great change from the uncoated boards. This was true expecially of the silicone samples, because silicone possess good dielectric properties over the frequency range from 1 to 100 mc. The data from this phase will be plotted to determine how these coatings behave over this frequency range when compared to epoxies and polyurethanes and will be presented in the next Quarterly Report.

PHASE B

Stage A

Investigation of Chemical stripping of conformal coating as a method of repairing printed wiring assembly.

The conclusions drawn from this investigation can be summarized as follows:-

(1) Epoxy and polyurethane coatings were softened and/or lifted when exposed to 14 of these solvents. The solvents which had no effect on these coatings will be discarded.

(2) Solvents A,B, and Q caused severe corrosion of copper. All other materials did not give evidence of corrosion.

(3) Type PP laminate was attached most severely by these solvents whereas type GB laminate was the least attached.

By the use of these strippings, both polyurethane and epoxy resin conformal coatings can be softened by swelling within 15 minutes after application of solvent stripper after which the resin can be scrapped off the circuitry.

Stage B

Investigation of mechanical stripping of conformal coating as a method of repairing printed wiring assembly.

In the use of the soldering run technique, it was found that a very hot room chars and redeposits the resin on the copper circuitry making it difficult to unsolder a connection. However, when a "cooler" temperature of the iron was used the resin coating softened which made removal easier.

General

A form letter was sent to various large electronic manufacturers enlisting their aid in the Phase B of this program. We have asked, in the letter, for any procedures that they use in removing conformal coatings to effect repair. As of this date, no answers have been received as yet.

PROGRAM FOR NEXT INTERVAL

(1) Complete Stages C and F of Phase A where needed.

(2) Phase B

a. Determine whether procedures evolved in Stages A,B and C are suitable for actual use. From this specify a standardized procedure for removing conformal coating.

b. After standard procedure is determined, recoat test patterns and subject to 10 day humidity.

(3) Complete Phase C.

IDENTIFICATION OF KEY PERSONNEL

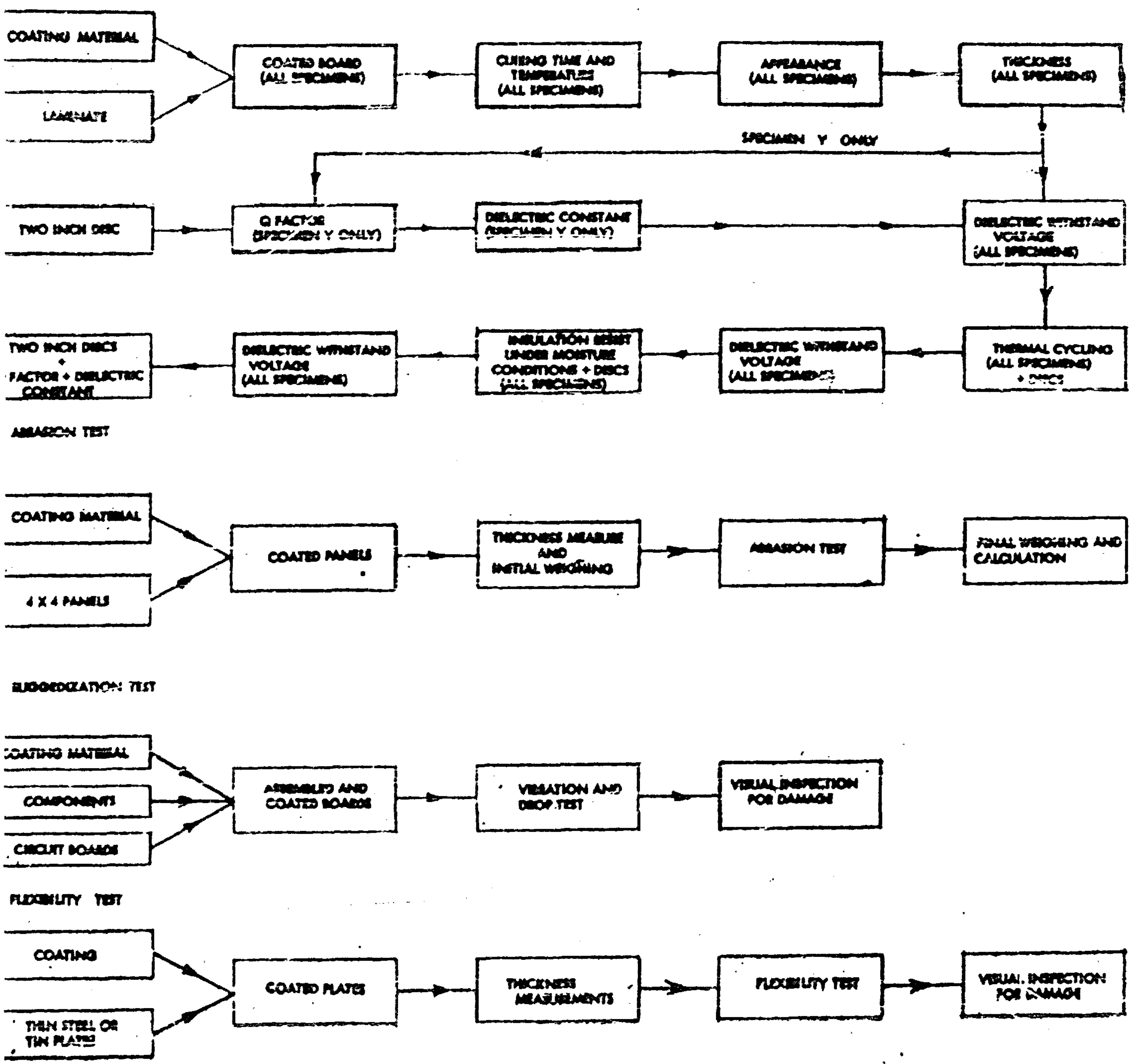
	TIME SPENT - HOURS
Mr. Anthony Beccasio Project Engineer	237
Mr. Ernesto Colon Technician	50 ½
Mr. Leonard Nero Statistician and Chemist	146½
Mr. Arthur Bethke Chemist	8
Mr. Felice LaSala Chief Chemist	2
TOTAL	444

APPENDIX

FLOW CHART FOR PHASE A TESTING

ELECTRICAL TESTING

Table I



PREPARED BY A.J.B. AUG.22,1961

TABLE II

COATING MANUFACTURERS

This table has been purposely omitted.

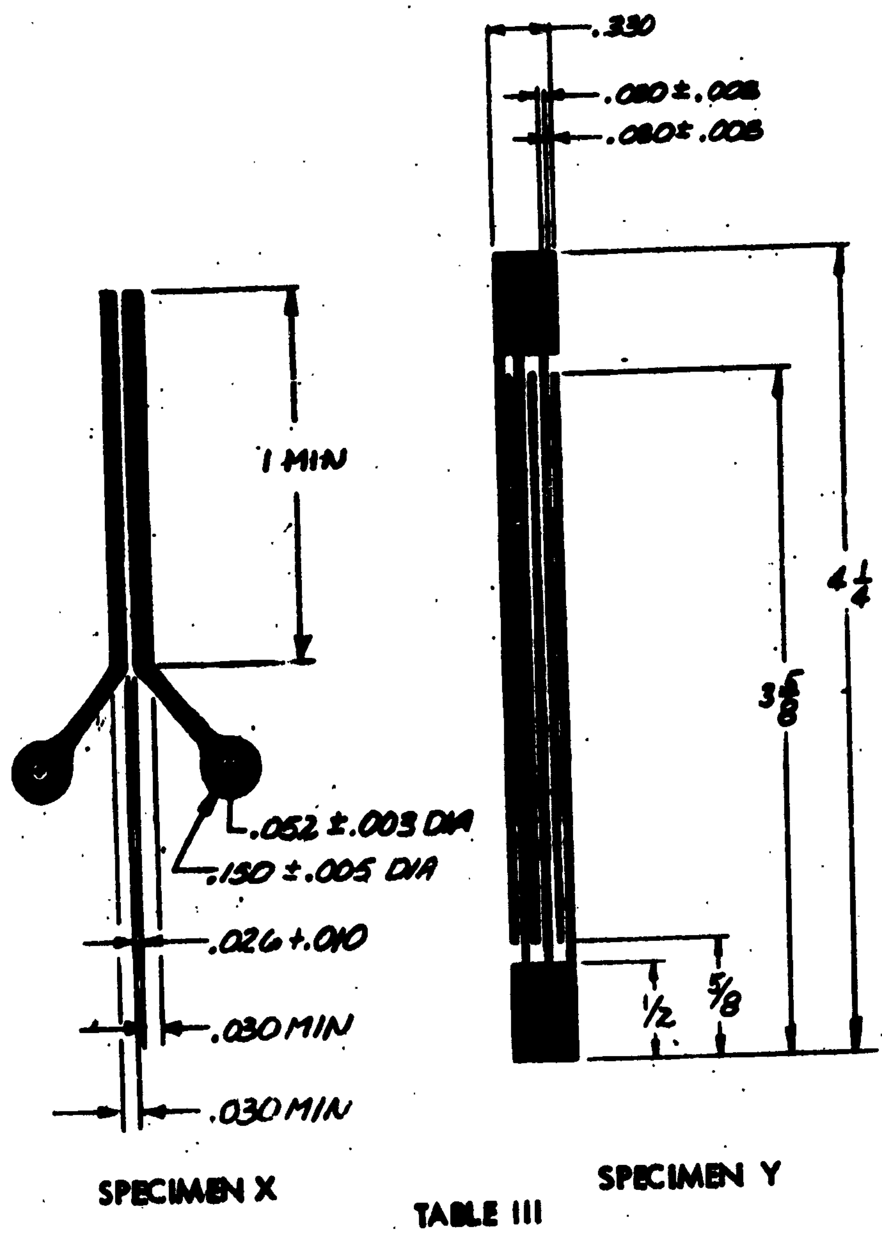
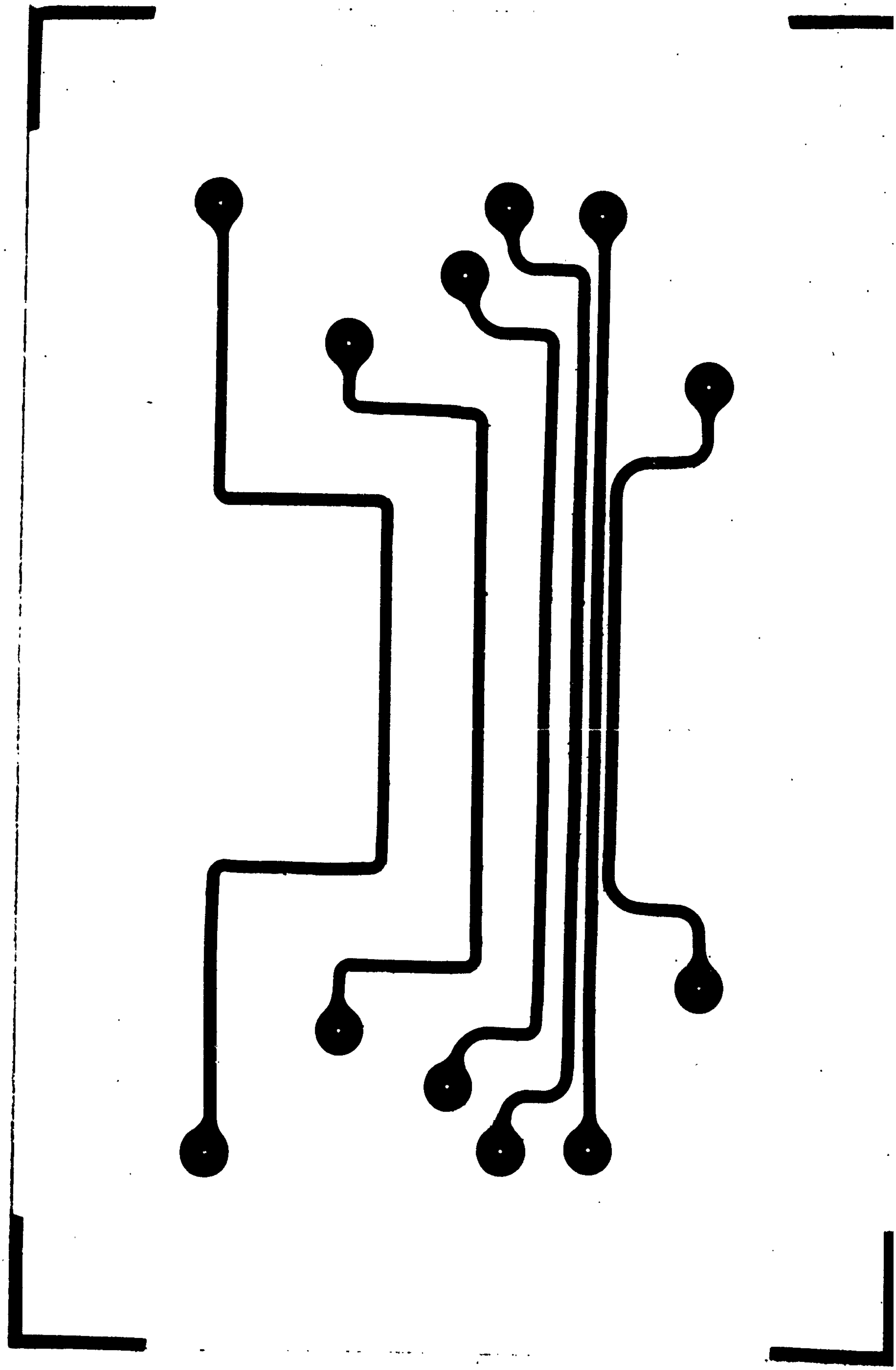


TABLE III
TEST PANELS

TABLE IV

TEST PLAN FOR PHASE C



PHASE C PATTERN

SCALE - 1:1

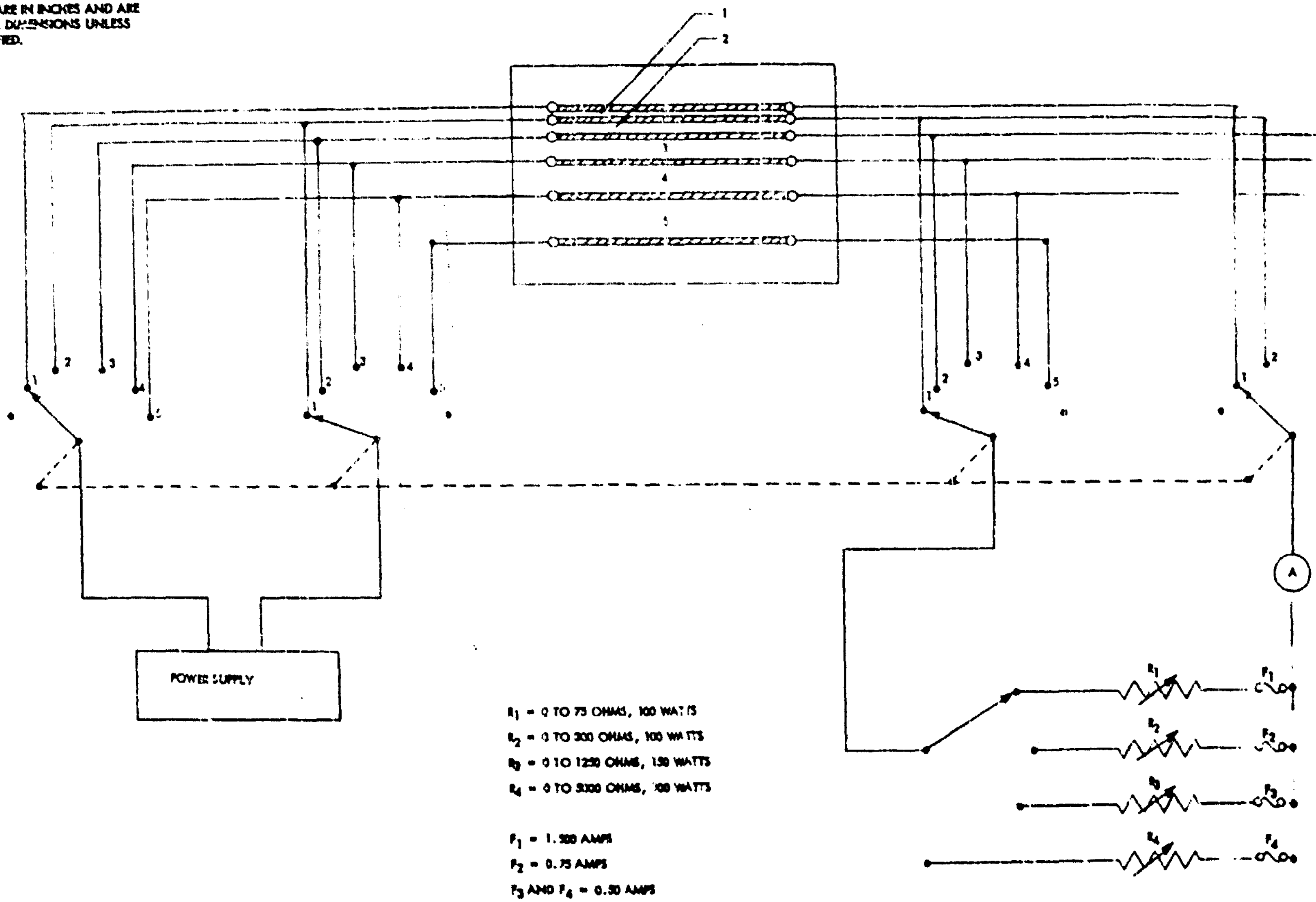
TABLE V CIRCUIT DIAGRAM FOR PHASE C

NOTE
DATA MARKED BY AN ASTERISK (*) ARE FOR INFORMATION ONLY, CONTRACTOR MAY, AT HIS OPTION, DEVIATE FROM THESE DETAILS

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL

NOTES:

1. ALL DIMENSIONS ARE IN INCHES AND ARE FINISHED END USE DIMENSIONS UNLESS OTHERWISE SPECIFIED.



R_1 = 0 TO 75 OHMS, 100 WATTS
R_2 = 0 TO 300 OHMS, 100 WATTS
R_3 = 0 TO 1250 OHMS, 150 WATTS
R_4 = 0 TO 5000 OHMS, 100 WATTS

F_1 = 1.500 AMPS
F_2 = 0.75 AMPS
F_3 AND F_4 = 0.50 AMPS

				TOLERANCES UNLESS OTHERWISE SPECIFIED	DR BY	MOTOROLA INC.		DEPARTMENT OF THE ARMY
				TWO PLACE DEC ± / ANGULAR DIM ±	CHK BY	ORDER NO.		U. S. ARMY SIGNAL MATERIEL SUPPORT AGENCY
				THREE PLACE DEC ± / HOLE DIM ±		SIGNAL CORPS		FORT MONMOUTH NEW JERSEY
				MATERIAL		REVIEWED		
NEXT ASSY	USED ON	NEXT ASSY	USED ON	FINISH		APPROVED		
*MOTOROLA APPLICATION		APPLICATION			RELEASE DATE	DATE	SCALE	CODE 80063

WHEN REFERRING TO THIS DRAWING STATE DRAWING NO., APPLICABLE ISSUE SYMBOL, IF ANY, AND DATE.

TABLE VI

ABRASION RESISTANCE DATA AND WEAR INDEX CALCULATIONS

Sample	Smpl Ident. no.	Initial wt. (grams)	Final wt. (grams)	Initial minus Final wts.	Wear index	Average wear index
Epoxy C	C-1 C-2 C-3	90.2147 94.1416 93.7376	90.1746 94.1044 93.6857	0.0401 0.0372 0.0519	0.0401 0.0372 0.0519	0.0431
Epoxy F	F-1 F-2 F-3	83.8601 83.5949 83.1827	83.8335 83.5695 83.1570	0.0266 0.0254 0.0257	0.133 0.127 0.129	0.130
Epoxy I	I-1 I-2 I-3	84.1654 84.2161 84.1402	84.1492 84.2026 84.1282	0.0162 0.0135 0.0120	0.081 0.068 0.060	0.070
Ureth. A	A-1 A-2 A-3	84.3278 83.7105 83.5620	84.3192 83.7102 83.5530	0.0086 0.0093 0.0090	0.043 0.047 0.045	0.0448
Ureth. B	B-1 B-2 B-3	84.3892 84.8955 84.8616	84.3790 84.8850 84.8512	0.0102 0.0105 0.0104	0.051 0.053 0.052	0.052
Ureth. G	G-1 G-2 G-3	83.8321 84.2541 84.3544	83.8135 84.2353 84.3365	0.0186 0.0188 0.0179	0.093 0.094 0.090	0.092

TABLE VII

SILICONE AND MFP COATING THICKNESSES

Smpl.	Laminate	Average thickness (inches)		
		Patt. 1	Patt. 2	Patt. 3
MFP. A	PP	0.003	0.004	0.004
	PE	0.002	0.002	0.003
	GF	0.002	0.002	0.003
	GB	0.002	0.003	0.003
	GE	0.004	0.004	0.003
MFP. B	PP	0.004	0.003	0.004
	PE	0.002	0.002	0.002
	GF	0.002	0.003	0.004
	GB	0.003	0.002	0.003
	GE	0.004	0.004	0.002
Silic A	GF	0.003	0.003	0.002
	GB	0.003	0.003	0.003
	GE	0.004	0.004	0.004
Silic B	GF	0.004	0.005	0.006
	GB	0.004	0.002	0.002
	GE	0.005	0.004	0.002

TABLE VIII

Q-FACTOR AND DISSIPATION FACTOR MEASUREMENTS OF MFP AND SILICONE COATINGS

Type and code	Laminate	Test specimen type	Average thick of panels	1 mc.		50 mc		100 mc.	
				Av. Q	Av. DF	Av. Q	Av. DF	Av. Q	Av. DF
MFP A	GE	control	-	60.4	0.016	104.0	0.009	103.3	0.010
		coated	0.004	6014	0.017	98.6	0.010	99.5	0.010
	GB	control	-	68.5	0.015	80.6	0.012	122.8	0.008
		coated	0.003	48.4	0.020	70.7	0.014	110.4	0.009
	GF	control	-	51.5	0.019	62.9	0.016	96.5	0.010
		coated	0.002	44.7	0.022	56.0	0.018	91.7	0.011
	PE	control	-	31.7	0.031	35.0	0.029	45.4	0.022
		coated	0.002	28.7	0.035	32.3	0.031	42.7	0.024
	PP	control	-	38.2	0.026	36.3	0.029	49.7	0.020
		coated	0.004	34.9	0.029	33.9	0.029	45.2	0.022
MFP B	GE	control	-	69.5	0.014	115.9	0.0085	108.8	0.009
		coated	0.004	61.7	0.016	109.6	0.009	105.1	0.010
	GB	control	-			113.8	0.009	107.4	0.009
		coated	0.003			102.4	0.010	84.6	0.012
	GF	control	-	74.2	0.013	127.3	0.008	119.2	0.008
		coated	0.003	67.0	0.015	125.0	0.008	115.4	0.009
	PE	control	-	28.6	0.035	53.6	0.019	46.0	0.021
		coated	0.002	27.5	0.037	51.5	0.019	40.0	0.025
	PP	control	-	36.2	0.027	58.3	0.017	51.8	0.019
		coated	0.004	36.6	0.027	57.3	0.017	51.8	0.019
Silicone A	GE	control	-	58.5	0.017	95.5	0.010	113.4	0.010
		coated	0.004	40.9	0.025	98.4	0.010	112.4	0.010
	GB	control	-	57.5	0.017	93.4	0.011	94.9	0.011
		coated	0.003	42.7	0.023	99.2	0.010	103.7	0.010
	GF	control	-	70.3	0.014	115.1	0.0086	97.2	0.010
		coated	0.003	56.2	0.018	115.7	0.0086	105.8	0.009
Silicone B	GE	control	-	63.4	0.016	132.4	0.0075	109.0	0.009
		coated	0.003	66.9	0.015	123.8	0.008	108.8	0.009
	GB	control	-	60.5	0.017	125.4	0.008	118.4	0.008
		coated	0.003	59.4	0.017	125.5	0.008	105.2	0.009
	GF	control	-	73.4	0.014	113.2	0.009	102.9	0.010
		coated	0.004	64.3	0.015	117.3	0.0085	108.6	0.009

TABLE IX EFFECT OF SOLVENTS ON COPPER-CLAD LAMINATES AND ON EPOXY AND POLYURETHANE COATINGS

CODE

(PP) XXXP --- X
(PE) EXXXP -- EX
(GE) G10 ---- E
(GB) G11 ---- B
GF ---- F
NE ----- No effect

Solvent	Corrosion 15' dip & air dry	Effect on Epoxy	Effect on Polyurethanes	Effect on Laminates Worst -- To --	Best
Acetone	O.K.	15' soft	15' soft	X F E EX	B
Solvent A	O.K.	NE	NE	NE	
Solvent B	Severe	30' soft	30' soft	X Rest	B NE
n-Butyl Acetate	O.K.	NE	NE	X Rest - NE	
Cellosolve Acetate	O.K.	NE	NE	X Rest - NE	
Solvent C	O.K.	30' soft	NE	X E F EX	B NE
Solvent D	Discolor	NE	15' lifted	X F E EX	B NE
Di Isobutyl Ketone	O.K.	NE	NE	NE	
Ethyl Acetate	O.K.	NE	NE	X F E EX	B NE
Solvent E	O.K.	30' soft	NE	X E EX F	B NE
Furfural	O.K.	30' soft	30' soft	X E F EX	B NE
Furfuryl Alcohol	O.K.	30' soft	3C lift	E X Rest - NE	
Solvent F	O.K.	NE	NE	NE	

TABLE IX (CONT.)

Solvent	Corrosion 15' dip & air dry	Effect on Epoxy	Effect on Polyurethanes	Effect on Laminates Worst -- To --	Best
Solvent G	O.K.	NE	NE	NE	
Solvent H	O.K.	NE	NE	NE	
Solvent I	O.K.	NE	NE	NE(GIO & X stained)	
Solvent J	O.K.	NE	5' lift	X F EX E	B NE
Solvent K	Coated copper	30' soft	5' lift	X EX E F	B NE
Solvent L	O.K.	30' soft	30' soft	X F E EX	B NE
Methyl Ethyl Ketone	O.K.	15' soft	15' soft	X F EX E	B
Methyl Iso-butyl Ketone	O.K.	NE	NE	X EX Rest - NE	
Solvent M	O.K.	NE	NE	X Rest - NE	
Solvent N	Discolor	15' soft	5' lift	X F E EX	
Solvent O	O.K.	30' soft	NE	X E Rest - NE	
Solvent P	O.K.	NE	NE	NE	
Tetrahydro-furfuryl Alcohol	O.K.	NE	NE	X E EX Rest - NE	
Solvent Q	Mild	15' lift	15' lift	X E F EX	B NE
Solvent R	Discolor	15' lift	15' lift	X EX F E	B NE